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Removal of Urbanisation Effects from the Central England Temperature Data-Sets

by

T P Legg

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Meteorological Office (Met. O. 13)
London Road
Bracknell
Berkshire RG12 2SZ

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REMOVAL OF URBANISATION EFFECTS FROM THE CENTRAL ENGLAND TEMPERATURE DATA-SETS

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Abstract

Urbanisation around the stations which are used to compute values of daily and monthly central England temperature is thought to have been occurring over recent years. We have evaluated the magnitude of the recent urbanisation trend, by comparing temperatures at the stations used with nearby rural stations. This has allowed corrections to the existing series since 1974 to be developed. The artificial warming trend was calculated to be around 0.1 deg C per 15-20 years; hence at present the differences amount to no more than 0.1 deg C but will become gradually larger in the future. The resulting series should be more representative of true fluctuations of temperature on the longer time-scales over central England in future. Staff resources have not allowed corrections to be produced before 1974, the period for which Manley's series was published.

1. Introduction

Series of daily and monthly central England temperature (CET) were produced by Manley (1953, 1974) and are regularly updated in Met O 13. Long-term and short-term trends and fluctuations can be studied from these time-series, and on time-scales of decades many interesting variations can be seen (Figure 1). Part of the warming trend during the present century may, however, be due to artificial effects as towns have increased in size around some of the stations used. Manley considered this problem but it is likely that CET suffers from some urbanisation bias before 1974. However we have concentrated here on ensuring that post-1974, and therefore future data, should not be further influenced by such biases. Of the four stations currently used to calculate CET, Malvern was thought to have suffered most from urbanisation, as the population of the town has steadily grown, and the results presented below confirm this.

The values of mean temperatures of stations currently used to provide daily and monthly CET have been compared with the values at other nearby candidate stations over a period of approximately the last thirty years, to ascertain whether any long-term relative trends have occurred. Corrections were then calculated for each month, and applied retrospectively to data since 1974. Application of corrections which vary from day to day with changes in circulation type were considered, but were dropped because this would have been too labour-intensive and because the sample size for a particular circulation type would have been small, resulting in statistical scatter.

We have now produced revised daily and monthly CET data-sets, the values on which, for recent years, are slightly lower than on the previous copies of the data-sets [which have now been archived].

The suite of computer programs which produce various kinds of output statistics and graphs of CET has also been revised to take account of the de-urbanisation. Some examples of the up-to-date output are presented towards the end of this work.

2. Choosing the stations

The choice of observing stations has had to take several factors into account. The stations should be located between central Lancashire and an area from the southern border of the Midlands to East Anglia, as this fits Manley's (1974) definition of Central England. One station is therefore required to represent the Lancashire Plain, with the remaining two being near the western and eastern extremities of the South Midlands. Stations with long periods of record are required, to keep possible inhomogeneities in the data due to changes of station location to a minimum; peculiarities such as frost hollows must of course be avoided. The idea of making small corrections to the calculated mean temperatures to allow for the inevitable small variations in the climatic mean temperature when one station is replaced by another was considered justifiable by Manley. Corrections to allow for apparent variations in climate caused artificially by urbanisation can therefore be regarded as justifiable too.

Since 1959, four stations have been used by Met O 13 to calculate CET. Each day the value of CET is evaluated from the mean of maximum and minimum temperatures at stations as follows:-

$$CET = 1/3[\text{Rothamsted} + \text{Malvern} + \tfrac{1}{2}(\text{Squires Gate} + \text{Ringway})] .$$

Of these stations, all apart from Rothamsted were suspected of suffering from urbanisation effects to some extent. The following candidate comparison stations were considered:-

(a) Malvern - (i) Luddington, (ii) Lyonshall, (iii) Pershore, (iv) Preston Wynne.
(b) Squires Gate - (i) Preston, (ii) Slaidburn.
(c) Ringway - (i) Knutsford, (ii) Macclesfield.

Digitised daily data for most of these stations begin in 1959. This gave approximately thirty years from which trends in the differences in mean temperature between pairs of stations could be worked out.

The relative trend between Squires Gate and either Preston or Slaidburn was not found to be significant and was neglected. The environments of these stations, moreover, are not comparable: Squires Gate is very near the coast (and hence is not really a suitable station itself); Preston (an urban station) and Slaidburn are much further inland; Slaidburn, moreover, has an upland site (192m above MSL).

Data for Knutsford was very incomplete, so this station was not considered further.

The positions of the four stations used since 1959 and the comparison stations are shown in Fig 2. A closer look at the environments of the original stations was given in Storey et al. (1985) (which should be read in conjunction with the present paper). The extent of growth of some of the towns is also illustrated (Fig 3), by comparing recent 1:50000 Ordnance Survey maps with thirty-year-old copies of maps from the One-Inch series. These maps clearly show the changes in urban extent during the period covered; the dates of the maps vary for different areas and are shown alongside.

The suitability of all the stations used will be discussed in greater detail in a future paper by Legg and Parker (1990). This will include complete sets of maps and photographs showing the surroundings of all the stations on a variety of space-scales.

3. Comparisons between pairs of stations; removal of trends

The urbanisation warming trends of Malvern and Ringway were obtained by comparing them with the nearby sites which have not become urbanised. The equations giving the trends are shown in Table I.

Malvern was found to have warmed most strongly relative to Luddington; the slightly slower trends when compared with Preston Wynne, Lyonshall, and Pershore suggest that these three latter stations may themselves have urbanised slightly over the period studied, though this is not borne out by Fig 3.

After inspecting the results given in Table I, we chose to construct a second series of daily CET values, starting in January 1959, replacing Malvern with ½(Luddington + Preston Wynne) and replacing Ringway with Macclesfield. The two series of daily values were then compared over the period January 1959 to December 1987. The differences between the calculated monthly means were obtained, and, for each of the twelve calendar months, a linear regression was performed with time (years) as the dependent variable. Fig 4 illustrates the warming trends. The warming trend of the original series relative to the new was strong (found to be significant using t-tests on the slope of the trend line) in all calendar months, as shown in Table II. The trends are strongest in April to July (equivalent to about 0.08 deg C per 10 years), and least in February and March (nearer 0.05 deg C per 10 years). Before using these results to apply corrections, the slopes of the regression lines were smoothed: the slope, b, for each month m was found from $(b_{m-1} + 2b_m + b_{m+1})/4$. The base year for applying the corrections was 1974, for the reasons given earlier, and the corrections for individual months (b*(year-1974)) were rounded to the nearest 0.1 deg C. Having corrected the monthly values, each of the daily values within a month was altered by a corresponding amount.

4. Using the revised CET data

Having produced new Central England Temperature series, we are now in a position to show some of the results obtained from the daily and monthly data. A selection of graphs and tables will be presented in this section. The exercise of de-urbanisation will hopefully have provided us with a series more representative of true temperature variations in "Central England" (as defined by Manley), free from urban effects since his original series ended (in 1974), and the two series should be homogeneous: any apparent changes in variance on any time-scale must be true (Wylie et al 1984).

Note that it is not clear whether the trends calculated here will be appropriate in future. Therefore it is recommended that in about ten years a revised set of calculations is carried out so that future corrections do not extrapolate out-of-date assumptions.

At present the urbanisation corrections amount to 0.1 deg C in all months of the year. Thus all daily values for 1989, for example (shown in Figure 5), have been reduced by 0.1 deg C from the original values. Monthly values, shown in the rankings for a period since the beginning of this century (Table IVa), have been cooled, and hence values from recent years have generally a lower ranking (look at, for example, the months of Summer 1989, and compare with the results that would be obtained if 0.1 deg C were added to each month's value). Similar seasonal values and rankings are shown in Table IVb.

The examples shown in this section will be much expanded upon in the near future when a detailed paper on the characteristics of the CET data-sets is produced.

5. References

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DIAGRAMS

Fig 1 40-year running means of monthly (January, April, July, October) and annual CET, showing long-term fluctuations.

Fig 2 The locations of all the stations used in the present study.

Fig 3 Growth of urban areas: new maps compared with old.

Fig 4 Trend lines which show the warming of pairs of stations relative to each other.

Fig 5 Daily values and monthly means of CET for 1989.

Table I

Equations of trend lines showing relative temperature differences (monthly means) between stations as a function of time.

(a) Malvern vs Luddington

	Valid obs	Equation	Corln coefft	T-value	Years per deg C rise
January	28	T = -0.12 + 0.024Y	0.66	4.49	41
February	28	T = -0.01 + 0.018Y	0.57	3.57	56
March	29	T = 0.01 + 0.018Y	0.51	3.07	55
April	29	T = -0.26 + 0.029Y	0.70	5.07	35
May	28	T = -0.19 + 0.026Y	0.60	3.80	39
June	28	T = -0.16 + 0.025Y	0.60	3.82	40
July	29	T = -0.08 + 0.023Y	0.62	4.09	44
August	29	T = 0.04 + 0.019Y	0.53	3.24	54
September	29	T = 0.18 + 0.012Y	0.35	1.92	83
October	27	T = 0.17 + 0.012Y	0.39	2.10	83
November	29	T = 0.37 + 0.011Y	0.34	1.86	94
December	28	T = 0.38 + 0.012Y	0.38	2.09	81
Year	29	T = 0.03 + 0.019Y	0.85	8.25	53

(b) Malvern vs Lyonshall

	Valid obs	Equation	Corln coefft	T-value	Years per deg C rise
January	28	T = 0.18 + 0.019Y	0.70	4.99	53
February	28	T = 0.50 + 0.011Y	0.39	2.18	94
March	29	T = 0.79 + 0.003Y	0.14	0.73	385
April	29	T = 0.72 + 0.007Y	0.32	1.73	143
May	29	T = 0.48 + 0.017Y	0.58	3.71	60
June	29	T = 0.72 + 0.013Y	0.43	2.46	76
July	29	T = 0.98 + 0.008Y	0.25	1.34	125
August	29	T = 0.82 + 0.012Y	0.33	1.82	83
September	29	T = 0.91 + 0.009Y	0.28	1.50	111
October	28	T = 0.55 + 0.015Y	0.42	2.36	68
November	29	T = 0.68 + 0.007Y	0.27	1.43	133
December	28	T = 0.39 + 0.013Y	0.42	2.33	79
Year	29	T = 0.66 + 0.011Y	0.66	4.62	93

(c) Malvern vs Pershore

	Valid obs	Equation	Corln coefft	T-value	Years per deg C rise
January	28	T = -0.14 + 0.014Y	0.38	2.07	73
February	29	T = -0.01 + 0.006Y	0.23	1.24	159
March	28	T = 0.42 - 0.003Y	-0.05	-0.24	--
April	28	T = -0.01 + 0.011Y	0.26	1.35	92
May	28	T = -0.04 + 0.100Y	0.21	1.12	102
June	28	T = 0.12 + 0.005Y	0.11	0.58	222
July	29	T = -0.17 + 0.012Y	0.34	1.90	84
August	28	T = -0.15 + 0.012Y	0.35	1.92	86
September	29	T = -0.05 + 0.006Y	0.20	1.05	159
October	27	T = -0.12 + 0.007Y	0.23	1.19	143
November	29	T = 0.03 + 0.008Y	0.26	1.41	133
December	28	T = 0.24 + 0.004Y	0.12	0.61	286
Year	29	T = 0.01 + 0.007Y	0.32	1.74	133

(d) Malvern vs Preston Wynne

	Valid obs	Equation	Corln coefft	T-value	Years per deg C rise
January	27	T = 0.46 + 0.009Y	0.29	1.50	115
February	27	T = 0.65 + 0.001Y	0.01	0.03	--
March	27	T = 0.85 - 0.003Y	-0.08	-0.41	--
April	29	T = 0.60 + 0.013Y	0.31	1.73	78
May	29	T = 0.67 + 0.014Y	0.44	2.53	69
June	29	T = 0.97 + 0.010Y	0.30	1.61	97
July	28	T = 0.71 + 0.021Y	0.52	3.14	48
August	29	T = 0.77 + 0.015Y	0.38	3.31	68
September	29	T = 0.83 + 0.010Y	0.32	1.77	101
October	27	T = 0.65 + 0.009Y	0.31	1.62	108
November	29	T = 0.52 + 0.011Y	0.42	2.38	88
December	28	T = 0.55 + 0.008Y	0.27	1.45	120
Year	29	T = 0.69 + 0.010Y	0.62	4.16	101

(e) Ringway vs Macclesfield

	Valid obs	Equation	Corln coefft	T-value	Years per deg C rise
January	29	T = 0.29 + 0.010Y	0.44	2.53	100
February	29	T = 0.50 + 0.005Y	0.18	0.97	206
March	29	T = 0.32 + 0.006Y	0.32	1.74	160
April	27	T = 0.26 + 0.009Y	0.49	2.80	110
May	28	T = 0.17 + 0.009Y	0.37	2.05	111
June	27	T =-0.12 + 0.019Y	0.65	4.34	53
July	29	T = 0.19 + 0.010Y	0.44	2.58	96
August	29	T = 0.38 + 0.004Y	0.19	1.02	263
September	29	T = 0.29 + 0.007Y	0.32	1.74	152
October	26	T = 0.08 + 0.014Y	0.62	3.83	71
November	28	T = 0.29 + 0.009Y	0.38	2.08	116
December	29	T = 0.35 + 0.007Y	0.30	1.63	133
Year	29	T = 0.25 + 0.009Y	0.72	5.37	109

Table II

Regression lines showing the trend of temperature differences with time:
Series A - Series B

where
Series A is [Rothamsted + Malvern + ½(Squires Gate + Ringway)]/3

and
Series B is [Rothamsted + ½(Luddington + Preston Wynne) +
+ ½(Squires Gate + Macclesfield)]/3

Month	Trend equation	Cor.coefft.	Smoothed b
January	$\Delta T = -0.332 - 0.0075(Y-1973)$	r=-0.668	-0.00591
February	$\Delta T = -0.311 - 0.0042(Y-1973)$	r=-0.437	-0.00505
March	$\Delta T = -0.319 - 0.0043(Y-1973)$	r=-0.407	-0.00538
April	$\Delta T = -0.375 - 0.0087(Y-1973)$	r=-0.658	-0.00712
May	$\Delta T = -0.363 - 0.0068(Y-1973)$	r=-0.539	-0.00764
June	$\Delta T = -0.398 - 0.0083(Y-1973)$	r=-0.632	-0.00815
July	$\Delta T = -0.426 - 0.0093(Y-1973)$	r=-0.718	-0.00825
August	$\Delta T = -0.397 - 0.0062(Y-1973)$	r=-0.532	-0.00660
September	$\Delta T = -0.369 - 0.0048(Y-1973)$	r=-0.442	-0.00558
October	$\Delta T = -0.326 - 0.0066(Y-1973)$	r=-0.528	-0.00585
November	$\Delta T = -0.361 - 0.0054(Y-1973)$	r=-0.537	-0.00549
December	$\Delta T = -0.360 - 0.0045(Y-1973)$	r=-0.400	-0.00548
[Year	$\Delta T = -0.372 - 0.0077(Y-1973)$	r=-0.778]	

Month	No correction necessary	Correct by 0.1 deg C	Correct by 0.2 deg C
January	until 1981	1982-1998	1999-2015
February	until 1982	1983-2002	2003-2022
March	until 1982	1983-2000	2001-2019
April	until 1980	1981-1994	1995-2008
May	until 1979	1980-1992	1993-2005
June	until 1979	1980-1991	1992-2003
July	until 1979	1980-1991	1992-2003
August	until 1980	1981-1995	1996-2010
September	until 1981	1982-1999	2000-2017
October	until 1981	1982-1998	1999-2015
November	until 1982	1983-2000	2001-2018
December	until 1982	1983-2000	2001-2018
(Year	until 1979	1980-1992	1993-2005)

Table III

New values of monthly mean Central England temperatures, 1974-1989.

These values are taken from Storey et al. (1985), and corrected for urbanisation; the table has been updated to 1989.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1974	5.9	5.4	5.8	8.2	11.0	13.9	15.2	15.2	12.1	7.8	6.8	8.1
1975	6.8	4.4	4.8	8.3	9.9	14.7	17.4	18.7	13.5	9.9	6.3	5.3
1976	5.9	4.5	4.8	8.1	12.1	17.0	18.7	17.6	13.4	10.6	6.3	2.0
1977	2.8	5.2	6.9	7.2	10.6	12.2	15.9	15.2	13.3	11.8	6.6	6.1
1978	3.4	2.8	6.7	6.5	11.7	13.7	14.8	15.0	14.2	11.9	8.5	3.9
1979	-0.4	1.2	4.7	7.8	10.0	13.9	16.2	14.9	13.5	11.3	6.8	5.8
1980	2.3	5.7	4.7	8.8	11.2	13.8	14.7	15.9	14.7	9.0	6.6	5.6
1981	4.9	3.0	7.9	7.8	11.2	13.2	15.5	16.2	14.5	8.6	7.8	0.3
1982	2.6	4.8	6.1	8.6	11.6	15.5	16.5	15.7	14.2	10.1	8.0	4.4
1983	6.7	1.7	6.4	6.8	10.3	14.4	19.5	17.3	13.7	10.5	7.5	5.6
1984	3.8	3.3	4.7	8.1	9.9	14.5	16.9	17.6	13.7	11.1	8.0	5.2
1985	0.8	2.1	4.7	8.3	10.9	12.7	16.2	14.6	14.6	11.0	4.1	6.3
1986	3.5	-1.1	4.9	5.8	11.1	14.8	15.9	13.7	11.3	11.0	7.8	6.2
1987	0.8	3.6	4.1	10.3	10.1	12.8	15.9	15.6	13.6	9.7	6.5	5.6
1988	5.3	4.9	6.4	8.2	11.9	14.4	14.7	15.2	13.2	10.4	5.2	7.5
1989	6.1	5.9	7.5	6.6	13.0	14.6	18.2	16.6	14.7	11.7	.	.

TABLE IVa

RANKED TEMPERATURE VALUES FOR EACH MONTH AND ANNUALLY
CENTRAL ENGLAND TEMPERATURE - - - 1901-1999

RANK	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	ANNUAL	RETURN-PERIOD WARMER	RETURN-PERIOD COLDER
1	75(1916)	71(1945)	88(1957)	105(1943)	135(1947)	170(1976)	195(1983)	186(1975)	163(1949)	130(1959)	94(1938)	81(1974)	1081(1949)	100.34	1.01
2	73(1961)	71(1903)	81(1938)	103(1987)	128(1919)	163(1970)	188(1976)	185(1947)	153(1989)	128(1921)	87(1939)	81(1934)	1048(1938)	52.69	1.02
3	68(1975)	69(1961)	83(1948)	102(1944)	134(1952)	163(1940)	185(1921)	181(1911)	152(1961)	128(1988)	86(1978)	75(1988)	1046(1921)	33.53	1.03
4	67(1983)	68(1925)	82(1981)	101(1945)	123(1944)	161(1955)	181(1999)	180(1995)	151(1958)	125(1960)	85(1953)	69(1953)	1027(1945)	24.22	1.04
5	63(1932)	68(1914)	79(1991)	100(1981)	120(1989)	160(1960)	181(1934)	175(1964)	148(1989)	119(1979)	85(1951)	69(1918)	1018(1938)	19.06	1.05
6	61(1989)	65(1918)	79(1945)	100(1949)	120(1970)	156(1933)	181(1911)	173(1976)	148(1947)	119(1954)	84(1913)	68(1954)	1008(1976)	15.71	1.07
7	59(1976)	61(1943)	75(1989)	98(1948)	120(1918)	155(1982)	180(1901)	173(1933)	148(1933)	118(1945)	82(1983)	68(1924)	1005(1911)	13.36	1.08
8	59(1974)	60(1900)	74(1950)	98(1914)	119(1911)	155(1947)	179(1933)	173(1983)	147(1989)	118(1977)	81(1948)	67(1942)	1003(1983)	11.82	1.09
9	58(1944)	58(1989)	74(1921)	96(1982)	118(1980)	154(1964)	178(1955)	171(1958)	147(1980)	118(1908)	80(1984)	67(1912)	1003(1943)	10.29	1.11
10	57(1938)	58(1948)	73(1998)	94(1998)	118(1989)	153(1949)	175(1983)	170(1932)	146(1985)	117(1988)	80(1982)	66(1971)	1000(1957)	9.22	1.12
11	56(1933)	58(1935)	73(1933)	93(1985)	118(1917)	153(1930)	173(1979)	170(1944)	145(1934)	117(1948)	78(1986)	65(1921)	1000(1948)	8.36	1.14
12	56(1923)	58(1989)	73(1987)	93(1984)	117(1982)	152(1998)	173(1948)	168(1937)	145(1981)	113(1979)	78(1981)	64(1910)	1000(1975)	7.65	1.15
13	55(1949)	57(1980)	72(1980)	88(1965)	116(1953)	152(1957)	173(1938)	168(1948)	145(1941)	113(1971)	78(1970)	63(1985)	998(1934)	7.04	1.17
14	55(1957)	57(1988)	72(1912)	88(1937)	115(1940)	152(1917)	173(1941)	166(1928)	144(1970)	111(1984)	78(1931)	62(1988)	994(1981)	6.53	1.18
15	55(1949)	57(1948)	71(1936)	88(1948)	114(1928)	151(1941)	171(1935)	165(1988)	144(1965)	111(1963)	78(1917)	62(1911)	988(1914)	6.08	1.20
16	54(1948)	56(1939)	71(1903)	88(1920)	112(1945)	151(1938)	170(1935)	165(1982)	144(1938)	110(1988)	78(1988)	61(1977)	984(1982)	5.70	1.21
17	53(1988)	55(1932)	70(1967)	86(1957)	112(1932)	150(1953)	170(1928)	165(1938)	144(1988)	110(1985)	75(1903)	60(1988)	984(1953)	5.36	1.23
18	53(1953)	55(1923)	68(1977)	86(1930)	112(1933)	149(1963)	170(1904)	165(1973)	143(1932)	110(1985)	74(1944)	59(1972)	983(1933)	5.05	1.25
19	53(1906)	54(1974)	68(1938)	86(1939)	111(1978)	149(1934)	170(1947)	163(1988)	143(1988)	108(1981)	74(1988)	58(1972)	980(1913)	4.78	1.26
20	52(1937)	54(1967)	67(1978)	86(1933)	101(1918)	148(1988)	168(1904)	163(1938)	142(1982)	108(1913)	73(1983)	58(1948)	977(1988)	4.54	1.28
21	52(1988)	54(1912)	67(1908)	86(1912)	110(1988)	148(1972)	168(1971)	163(1918)	142(1978)	108(1908)	73(1949)	58(1988)	973(1984)	4.32	1.30
22	52(1980)	53(1987)	66(1982)	87(1984)	110(1943)	148(1988)	168(1988)	163(1938)	142(1985)	108(1987)	73(1938)	58(1922)	973(1980)	4.12	1.32
23	48(1981)	53(1980)	66(1938)	87(1983)	110(1980)	147(1975)	168(1982)	161(1981)	142(1938)	108(1988)	72(1947)	57(1988)	972(1988)	3.94	1.34
24	48(1943)	53(1938)	66(1978)	87(1940)	117(1978)	147(1988)	168(1953)	161(1933)	141(1984)	108(1987)	72(1948)	57(1948)	971(1938)	3.77	1.36
25	47(1984)	52(1977)	65(1988)	87(1938)	117(1988)	147(1938)	166(1987)	161(1928)	141(1951)	107(1978)	71(1988)	57(1932)	988(1971)	3.62	1.38
26	47(1988)	52(1965)	66(1943)	87(1984)	117(1988)	147(1951)	166(1948)	160(1943)	141(1981)	106(1978)	71(1984)	56(1987)	988(1938)	3.48	1.40
27	46(1987)	52(1938)	65(1983)	86(1988)	116(1988)	147(1910)	165(1988)	160(1938)	141(1913)	103(1972)	70(1988)	56(1933)	981(1974)	3.35	1.43
28	46(1986)	51(1938)	64(1988)	86(1947)	116(1971)	147(1908)	165(1944)	160(1918)	140(1971)	106(1947)	69(1954)	56(1930)	980(1987)	3.23	1.45
29	45(1973)	51(1910)	64(1983)	86(1931)	116(1953)	146(1988)	163(1943)	160(1914)	140(1943)	106(1943)	68(1940)	56(1941)	957(1947)	3.12	1.47
30	45(1971)	49(1988)	64(1980)	86(1988)	116(1984)	146(1948)	163(1937)	160(1978)	140(1917)	106(1934)	66(1935)	56(1986)	957(1988)	3.01	1.50
31	45(1967)	48(1982)	63(1988)	83(1985)	116(1918)	145(1984)	163(1951)	159(1988)	138(1988)	106(1918)	66(1978)	55(1951)	957(1980)	2.91	1.52
32	45(1938)	48(1961)	63(1988)	83(1978)	115(1938)	145(1914)	163(1948)	159(1948)	138(1988)	106(1910)	66(1974)	55(1918)	956(1970)	2.82	1.55
33	48(1913)	48(1913)	63(1988)	83(1988)	115(1981)	145(1911)	161(1938)	159(1933)	138(1911)	105(1933)	66(1938)	54(1988)	956(1944)	2.73	1.58
34	44(1988)	48(1911)	63(1937)	82(1988)	115(1901)	144(1988)	161(1978)	158(1982)	138(1933)	103(1938)	66(1918)	53(1975)	956(1937)	2.65	1.60
35	43(1982)	47(1988)	62(1973)	82(1974)	114(1973)	144(1983)	160(1984)	157(1952)	138(1981)	105(1988)	66(1914)	53(1938)	954(1973)	2.58	1.63
36	42(1980)	47(1948)	62(1988)	82(1972)	114(1948)	144(1981)	160(1937)	157(1937)	133(1986)	105(1927)	66(1982)	53(1931)	950(1918)	2.50	1.66
37	42(1938)	46(1978)	62(1989)	82(1938)	114(1944)	144(1953)	160(1932)	157(1938)	138(1953)	105(1933)	67(1988)	53(1915)	948(1977)	2.44	1.70
38	42(1933)	46(1971)	62(1913)	82(1980)	114(1938)	144(1982)	160(1928)	157(1907)	138(1948)	104(1908)	65(1930)	52(1944)	948(1964)	2.37	1.73
39	41(1934)	46(1964)	61(1982)	80(1918)	114(1931)	144(1943)	160(1917)	157(1918)	138(1938)	104(1982)	65(1977)	51(1947)	945(1988)	2.31	1.76
40	41(1918)	44(1978)	61(1914)	81(1984)	114(1913)	144(1942)	160(1912)	156(1937)	137(1944)	104(1942)	65(1948)	51(1933)	945(1948)	2.25	1.80
41	41(1904)	44(1982)	61(1910)	81(1978)	113(1988)	144(1938)	160(1989)	156(1971)	137(1933)	104(1941)	66(1941)	48(1973)	943(1930)	2.20	1.84
42	39(1972)	44(1988)	60(1983)	81(1988)	113(1934)	144(1931)	159(1987)	156(1950)	136(1987)	104(1937)	65(1932)	48(1948)	943(1906)	2.14	1.87
43	39(1961)	44(1982)	60(1940)	81(1913)	113(1989)	144(1930)	159(1986)	156(1940)	136(1948)	104(1985)	65(1987)	48(1938)	942(1978)	2.09	1.91
44	39(1951)	43(1973)	59(1974)	80(1988)	112(1981)	144(1913)	158(1977)	155(1901)	136(1933)	104(1988)	65(1988)	47(1985)	940(1958)	2.03	1.96
45	38(1944)	43(1972)	59(1954)	80(1934)	112(1920)	143(1919)	158(1988)	155(1964)	136(1938)	104(1908)	65(1937)	47(1988)	941(1980)	2.00	2.00
46	38(1980)	43(1933)	58(1938)	80(1921)	112(1988)	143(1913)	158(1930)	154(1928)	135(1937)	103(1983)	64(1988)	46(1914)	940(1950)	1.96	2.05
47	38(1918)	43(1933)	57(1918)	79(1971)	112(1964)	143(1908)	158(1927)	154(1981)	135(1978)	103(1914)	64(1987)	46(1937)	939(1932)	1.91	2.09
48	38(1911)	43(1915)	56(1953)	79(1987)	112(1948)	143(1905)	158(1954)	154(1957)	135(1975)	101(1982)	64(1933)	46(1932)	935(1912)	1.87	2.14
49	37(1970)	41(1980)	53(1930)	79(1915)	112(1927)	142(1938)	158(1948)	154(1934)	135(1937)	101(1960)	63(1978)	45(1957)	932(1936)	1.84	2.20
50	37(1936)	39(1931)	52(1988)	78(1981)	112(1918)	141(1988)	158(1914)	154(1928)	134(1978)	101(1948)	63(1973)	44(1988)	931(1933)	1.80	2.25
51	37(1982)	39(1987)	52(1944)	78(1978)	111(1988)	141(1937)	158(1928)	154(1925)	134(1937)	101(1933)	63(1972)	44(1933)	930(1968)	1.76	2.31
52	37(1914)	39(1934)	52(1942)	77(1987)	111(1988)	141(1932)	158(1906)	154(1911)	134(1915)	101(1928)	63(1943)	43(1970)	928(1985)	1.73	2.37
53	36(1958)	38(1916)	52(1915)	77(1982)	111(1942)	140(1937)	158(1973)	154(1908)	133(1977)	101(1924)	63(1912)	43(1930)	926(1951)	1.70	2.44
54	36(1912)	37(1981)	52(1911)	77(1931)	111(1903)	140(1951)	158(1972)	153(1928)	133(1943)	99(1975)	62(1944)	42(1987)	925(1924)	1.66	2.50
55	36(1907)	36(1987)	51(1948)	76(1934)	110(1974)	139(1978)	155(1981)	153(1917)	133(1934)	98(1948)	62(1930)	42(1988)	923(1928)	1.63	2.58
56	36(1905)	36(1944)	51(1948)	76(1980)	110(1956)	139(1974)	155(1923)	153(1913)	133(1914)	98(1937)	62(1927)	42(1900)	923(1999)	1.60	2.65
57	35(1986)	36(1941)	51(1941)	76(1939)	110(1951)	138(1959)	153(1942)	152(1959)	132(1928)	97(1957)	61(1934)	39(1978)	924(1981)	1.58	2.73
58	35(1910)	34(1982)	51(1905)	76(1923)	110(1908)	139(1984)	155(1938)	152(1977)	131(1900)	97(1933)	61(1911)	38(1900)	921(1984)	1.55	2.82
59	35(1900)	34(1934)	49(1988)	76(1907)	109(1985)	138(1912)	154(1918)	152(1974)	131(1933)	97(1923)	60(1973)	38(1938)	920(1927)	1.52	2.91
60	35(1901)	33(1984)	49(1971)	75(1985)	108(1988)	138(1902)	153(1938)	152(1923)	130(1983)	97(1904)	60(1971)	38(1900)	918(1972)	1.50	3.01
61	34(1978)	33(1964)	48(1985)	75(1911)	108(1984)	138(1901)	153(1931)	152(1913)	130(1916)	97(1901)	62(1981)	38(1940)	918(1918)	1.47	3.12
62	34(1964)	31(1988)	48(1978)	75(1908)	108(1915)	138(1900)	153(1924)	152(1910)	128(1933)	96(1930)	60(1936)	38(1923)	916(1925)	1.45	3.23
63	34(1958)	31(1908)	48(1975)	74(1988)	108(1914)	138(1934)	153(1916)	151(1972)	128(1920)	96(1940)	59(1928)	37(1904)	916(1910)	1.43	3.35
64	33(1985)	30(1981)	48(1934)	74(1988)	108(1908)	138(1958)	153(1903)	151(1948)	128(1932)	96(1929)	58(1982)	36(1984)	913(1985)	1.40	3.48
65	33(1953)	29(1970)	47(1985)	73(1983)	107(1944)	137(1982)	152(1974)	151(1904)	128(1900)	95(1928)	57(1900)	36(1944)	910(1901)	1.38	3.62
66	32(1931)	29(1932)	47(1984)	73(1910)	107(1934)	137(1978)	152(1970)	150(1978)	125(1940)	95(1926)	56(1983)	36(1943)	910(1932)	1.36	3.77
67	29(1986)	29(1908)	47(1980)	73(1908)	107(1930)	137(1982)	152(1963)	150(1950)	125(1928)	94(1953)	56(1933)	34(1929)	908(1941)	1.34	3.94
68	29(1954)	28(1978)	47(1978)	73(1905)	106(1977)	136(1926)	152(1961)	149(1979)	124(1982)	94(1951)	55(1932)	34(1901)	908(1923)	1.32	4.12
69	29(1919)	28(1907)	47(1932)	72(1977)	106(1953)	136(1948)	152(1938)	149(1925)	127(1954)	94(1938)	55(1936)	33(1980)	905(1987)	1.30	4.32
70	28(1977)	28(1954)	46(1922)	72(1986)	105(1972)	136(1944)	152(1930)	149(1931)	127(1919)	93(1944)	54(1918)	33(1933)	905(1948)	1.28	4.54
71	28(1952)	28(1940)	43(1964)	71(1918)	105(1932)	134(1954)	151(1962)	147(1988)	126(1982)	93(1918)	54(1908)	32(1938)	905(1940)	1.26	4.78
72	28(1948)	26(1936)	43(1908)	70(1972)	104(1937)	133(1989)	151(1960)	147(1948)	125(1957)	93(1911)	54(1987)	31(1948)	900(1909)	1.25	5.05
73	26(1982)	25(1930)	43(1904)	69(1956)	103(1908)	133(1918)	151(1940)	147(1941)	125(1944)	92(1935)	52(1908)	30(1968)	900(1904)	1.23	5.36
74	26(1958)	23(1901)	42(1931)	69(1932)	104(1987)	133(1904)	150(1958)	147(1908)	125(1927)	91(1915)	52(1904)	30(1937)	899(1931)	1.21	5.70
75	25(1908)	21(1985)	41(1987)	68(1924)	103(1983)	132(1981)	150(1946)	146(1906)	125(1923)	90(1930)	51(1937)	30(1908)	895(1985)	1.20	6.08
76	23(1980)	18(1968)	41(1951)	68(1983)	103(1962)	131(1958)	148(1954)	145(1918)	124(1910)	90(1973)	49(1942)	28(1952)	893(1915)	1.18	6.53
77	21(1947)	18(1919)	41(1924)	68(1981)	103(1957)	131(1948)	147(1988)	144(1909)	123(1904)	88(1964)	48(1905)	28(1935)	885(1965)	1.17	7.04
78	21(1933)	18(1963)	41(1901)	68(1928)	102(1905)	130(1933)	147(1980)	144(1982)	124(1905)	88(1962)	48(1908)	28(1925)	884(1907)	1.15	7.65
79	16(1958)	15(1908)	37(1970)	67(1970)	101(1987)	129(1958)	147(1908)	144(1931)	123(1995)	88(1932)	48(1901)	26(1963)	883(1898)	1.14	8.36
80	10(1917)	11(1979)	37(1988)	67(1918)	101(1981)	128(1987)	146(1915)	143(1983)	122(1982)	88(1931)	46(1921)	23(1917)	883(1908)	1.12	9.22
81	13(1985)	11(1955)	37(1909)	66(1988)	100(1978)	127(1985)	146(1913)	143(1907)	121(1974)	88(1981)	45(1988)	21(1981)	880(1973)	1.11	10.29
82	9(1942)	10(1969)	36(1947)	66(1978)	98(1984)	125(1927)	146(1909)	143(1933)	119(1918)	82(1939)	42(1982)	21(1927)	874(1986)	1.09	11.62
83	8(1987)	9(1917)	36(1937)	64(1941)	98(1973)	125(1923)	142(1954)	143(1902)	119(1909)	82(1922)	41(1985)	20(1976)	867(1922)	1.08	13.36
84	8(1995)	4(1929)	36(1919)	64(1903)	98(1935)	124(1971)	142(1910)	141(1924)	117(1972)	82(1912)	38(1925)	18(1916)	858(1962)	1.07	15.71
85	5(1941)	1(1942)	33(1949)	63(1936)	98(1984)	124(1907)	141(1920)	137(1906)	115(1931)	81(1926)	33(1923)	18(1962)	855(1909)	1.06	19.06
86	4(1945)	-2(1956)	33(1916)	60(1908)	97(1955)	122(1977)	141(1907)	136(1922)	115(1925)	78(1974)	33(1919)	16(1933)	850(1917)	1.04	24.22
87	-4(1979)	-7(1963)	32(1955)	58(1986)	94(1941)	118(1972)	140(1965)	136(1920)	113(1906)	75(1917)	32(1910)	11(1950)	848(1918)	1.03	33.23
88	-13(1940)	-10(1986)	32(1917)	55(1922)	92(1923)	118(1916)	139(1919)	135(1956)	111(1912)	74(1919)	29(1915)	3(1981)	847(1963)	1.02	52.89
89	-21(1963)	-18(1947)	28(1962)	54(1917)	88(1902)	118(1909)	137(1922)	129(1912)	107(1952)	71(1905)	***(1989)	***(1989)	*****(1989)	1.01	129.54

(CET DATA FROM 1974 ONWARDS HAVE BEEN DE-URBANISED)

THESE VALUES ARE ACTUALS
MONTHLY VALUES ARE GIVEN IN TENTHS DEG C, AND ANNUAL MEANS IN HUNDREDTHS

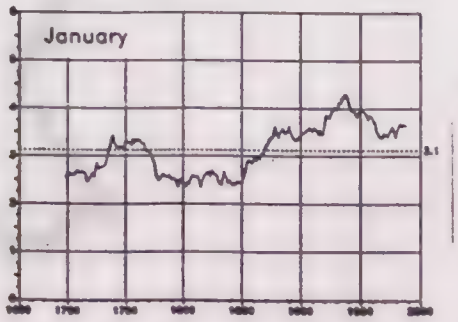
RANKED TEMPERATURE VALUES FOR EACH SEASON •••••••••••••••••••••••••••• 1901 TO 1989

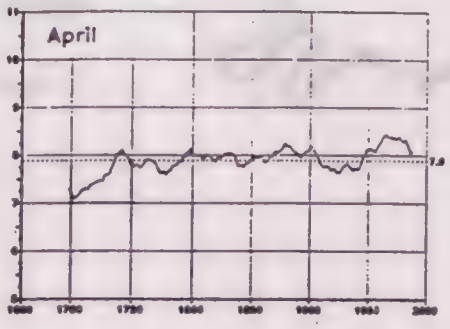
RANK	WINTER	SPRING	SUMMER	AUTUMN	RETURN PERIOD WARM	COLD
1	6.50 (1989)	10.07 (1945)	17.77 (1976)	11.53 (1978)	129.54	1.01
2	6.43 (1975)	9.87 (1952)	17.07 (1983)	11.53 (1959)	52.89	1.02
3	6.13 (1935)	9.83 (1959)	17.03 (1947)	11.53 (1949)	33.23	1.03
4	5.90 (1943)	9.73 (1961)	17.00 (1933)	11.23 (1938)	24.22	1.04
5	5.77 (1925)	9.60 (1943)	16.97 (1911)	11.17 (1945)	19.06	1.06
6	5.67 (1923)	9.57 (1948)	16.93 (1975)	11.13 (1913)	15.71	1.07
7	5.63 (1949)	9.47 (1957)	16.57 (1959)	10.97 (1970)	13.36	1.08
8	5.57 (1920)	9.43 (1933)	16.53 (1955)	10.97 (1968)	11.62	1.09
9	5.53 (1916)	9.37 (1960)	16.50 (1949)	10.93 (1984)	10.29	1.11
10	5.50 (1957)	9.37 (1912)	16.47 (1989)	10.90 (1947)	9.22	1.12
11	5.43 (1921)	9.13 (1938)	16.33 (1984)	10.77 (1982)	8.36	1.14
12	5.40 (1974)	9.07 (1940)	16.27 (1935)	10.77 (1969)	7.65	1.15
13	5.37 (1937)	9.07 (1920)	16.20 (1921)	10.77 (1958)	7.04	1.17
14	5.33 (1913)	9.03 (1989)	16.17 (1934)	10.73 (1963)	6.53	1.18
15	5.30 (1903)	8.97 (1981)	15.90 (1982)	10.70 (1961)	6.08	1.20
16	5.27 (1988)	8.97 (1921)	15.90 (1950)	10.70 (1908)	5.70	1.21
17	5.23 (1976)	8.93 (1944)	15.87 (1970)	10.70 (1906)	5.36	1.23
18	5.20 (1914)	8.90 (1914)	15.83 (1901)	10.67 (1953)	5.05	1.25
19	5.13 (1967)	8.83 (1988)	15.77 (1932)	10.67 (1951)	4.78	1.26
20	5.10 (1950)	8.80 (1927)	15.73 (1945)	10.63 (1946)	4.54	1.28
21	5.07 (1948)	8.77 (1982)	15.73 (1925)	10.57 (1983)	4.32	1.30
22	5.07 (1912)	8.77 (1964)	15.70 (1969)	10.57 (1977)	4.12	1.32
23	5.00 (1911)	8.77 (1950)	15.70 (1941)	10.53 (1979)	3.94	1.34
24	4.93 (1972)	8.77 (1949)	15.70 (1940)	10.53 (1929)	3.77	1.36
25	4.90 (1961)	8.67 (1939)	15.70 (1937)	10.50 (1954)	3.62	1.38
26	4.87 (1973)	8.60 (1926)	15.67 (1952)	10.50 (1941)	3.48	1.40
27	4.87 (1922)	8.57 (1947)	15.67 (1944)	10.50 (1921)	3.35	1.43
28	4.83 (1932)	8.57 (1946)	15.63 (1973)	10.43 (1971)	3.23	1.45
29	4.73 (1939)	8.57 (1928)	15.63 (1957)	10.43 (1934)	3.12	1.47
30	4.73 (1926)	8.57 (1913)	15.63 (1943)	10.40 (1948)	3.01	1.50
31	4.63 (1960)	8.53 (1911)	15.63 (1926)	10.37 (1939)	2.91	1.52
32	4.63 (1930)	8.50 (1953)	15.60 (1906)	10.30 (1981)	2.82	1.55
33	4.60 (1980)	8.50 (1942)	15.53 (1917)	10.23 (1960)	2.73	1.58
34	4.60 (1938)	8.47 (1918)	15.53 (1905)	10.20 (1933)	2.65	1.60
35	4.50 (1981)	8.43 (1963)	15.50 (1942)	10.17 (1928)	2.58	1.63
36	4.50 (1946)	8.40 (1972)	15.47 (1967)	10.17 (1924)	2.50	1.66
37	4.43 (1971)	8.37 (1967)	15.47 (1914)	10.13 (1964)	2.44	1.70
38	4.43 (1968)	8.33 (1976)	15.40 (1952)	10.13 (1955)	2.37	1.73
39	4.43 (1906)	8.33 (1974)	15.40 (1930)	10.13 (1916)	2.31	1.76
40	4.37 (1928)	8.33 (1937)	15.37 (1953)	10.13 (1914)	2.25	1.80
41	4.33 (1915)	8.30 (1978)	15.37 (1939)	10.10 (1980)	2.20	1.84
42	4.33 (1901)	8.30 (1965)	15.37 (1936)	10.10 (1976)	2.14	1.87
43	4.30 (1944)	8.30 (1936)	15.30 (1938)	10.10 (1930)	2.09	1.91
44	4.27 (1983)	8.30 (1905)	15.27 (1958)	10.07 (1943)	2.05	1.96
45	4.23 (1984)	8.27 (1956)	15.17 (1904)	10.07 (1920)	2.00	2.00
46	4.23 (1927)	8.23 (1980)	15.13 (1964)	10.03 (1986)	1.96	2.05
47	4.20 (1958)	8.23 (1977)	15.07 (1968)	10.00 (1935)	1.91	2.09
48	4.20 (1918)	8.23 (1966)	15.07 (1923)	10.00 (1903)	1.87	2.14
49	4.17 (1910)	8.23 (1935)	15.03 (1966)	9.97 (1907)	1.84	2.20
50	4.17 (1905)	8.20 (1973)	15.03 (1951)	9.93 (1987)	1.80	2.25
51	4.13 (1954)	8.20 (1954)	15.00 (1979)	9.90 (1985)	1.76	2.31
52	4.13 (1908)	8.20 (1910)	15.00 (1961)	9.90 (1975)	1.73	2.37
53	4.10 (1978)	8.20 (1903)	14.97 (1981)	9.90 (1967)	1.70	2.44
54	4.07 (1933)	8.17 (1987)	14.97 (1971)	9.90 (1957)	1.66	2.50
55	3.93 (1924)	8.13 (1971)	14.93 (1918)	9.90 (1956)	1.63	2.58
56	3.90 (1919)	8.13 (1907)	14.90 (1929)	9.83 (1966)	1.60	2.65
57	3.87 (1952)	8.10 (1930)	14.90 (1908)	9.77 (1973)	1.58	2.73
58	3.80 (1931)	8.10 (1929)	14.80 (1986)	9.77 (1940)	1.55	2.82
59	3.70 (1945)	8.07 (1968)	14.80 (1980)	9.77 (1936)	1.52	2.91
60	3.63 (1962)	8.07 (1919)	14.80 (1963)	9.77 (1917)	1.50	3.01
61	3.60 (1904)	8.07 (1901)	14.80 (1948)	9.77 (1911)	1.47	3.12
62	3.57 (1959)	8.03 (1934)	14.77 (1988)	9.73 (1927)	1.45	3.23
63	3.53 (1987)	8.00 (1925)	14.77 (1987)	9.73 (1902)	1.43	3.35
64	3.53 (1955)	7.97 (1985)	14.77 (1974)	9.63 (1942)	1.40	3.48
65	3.50 (1968)	7.97 (1915)	14.77 (1928)	9.63 (1937)	1.38	3.62
66	3.50 (1964)	7.97 (1904)	14.77 (1915)	9.60 (1988)	1.36	3.77
67	3.47 (1953)	7.83 (1983)	14.73 (1927)	9.53 (1972)	1.34	3.94
68	3.43 (1909)	7.80 (1970)	14.70 (1946)	9.50 (1962)	1.32	4.12
69	3.33 (1977)	7.80 (1909)	14.70 (1931)	9.47 (1926)	1.30	4.32
70	3.33 (1965)	7.77 (1931)	14.70 (1913)	9.47 (1901)	1.28	4.54
71	3.30 (1970)	7.77 (1923)	14.70 (1910)	9.43 (1932)	1.26	4.78
72	3.20 (1902)	7.70 (1916)	14.63 (1919)	9.40 (1950)	1.25	5.05
73	3.17 (1969)	7.70 (1902)	14.53 (1965)	9.37 (1931)	1.23	5.36
74	3.17 (1934)	7.67 (1975)	14.50 (1985)	9.33 (1944)	1.21	5.70
75	3.13 (1907)	7.63 (1906)	14.50 (1978)	9.27 (1965)	1.20	6.08
76	3.03 (1936)	7.60 (1922)	14.50 (1916)	9.13 (1904)	1.18	6.53
77	2.93 (1956)	7.57 (1984)	14.43 (1977)	9.03 (1909)	1.17	7.04
78	2.93 (1951)	7.57 (1908)	14.43 (1962)	8.90 (1974)	1.15	7.65
79	2.90 (1986)	7.53 (1924)	14.43 (1924)	8.90 (1918)	1.14	8.36
80	2.70 (1985)	7.50 (1979)	14.30 (1912)	8.77 (1922)	1.12	9.22
81	2.60 (1941)	7.40 (1958)	14.30 (1902)	8.77 (1910)	1.11	10.29
82	2.57 (1982)	7.40 (1955)	14.20 (1903)	8.53 (1912)	1.09	11.62
83	2.20 (1942)	7.37 (1932)	14.17 (1972)	8.50 (1925)	1.08	13.36
84	1.70 (1929)	7.30 (1969)	14.13 (1956)	8.50 (1923)	1.07	15.71
85	1.57 (1979)	7.27 (1986)	14.07 (1954)	8.43 (1915)	1.06	19.06
86	1.47 (1940)	7.13 (1917)	14.03 (1920)	8.13 (1905)	1.04	24.22
87	1.47 (1917)	7.00 (1951)	13.93 (1909)	7.90 (1952)	1.03	33.23
88	1.13 (1947)	6.97 (1941)	13.70 (1922)	7.80 (1919)	1.02	52.89
89	-0.33 (1963)	6.93 (1962)	13.60 (1907)	••••• (1989)	1.01	129.54

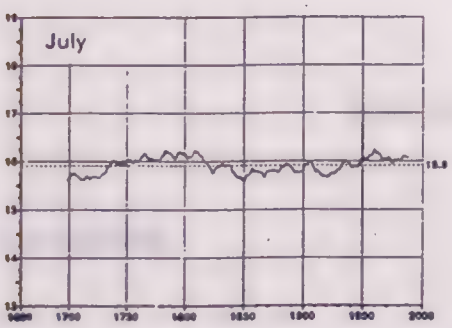
••••••••••••••••••••••••••

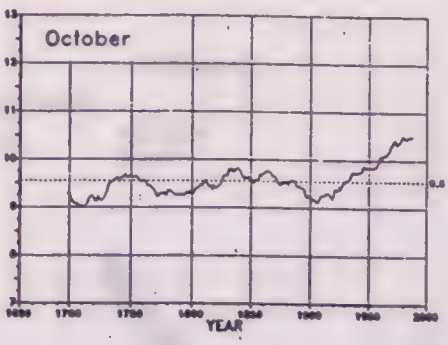
FIG 1. Mean monthly values of

Central England Temperature 1659 to 1988









Notes:-

Means plotted as broken line

Running means plotted on final year of period

40 weights were used common value 1.0

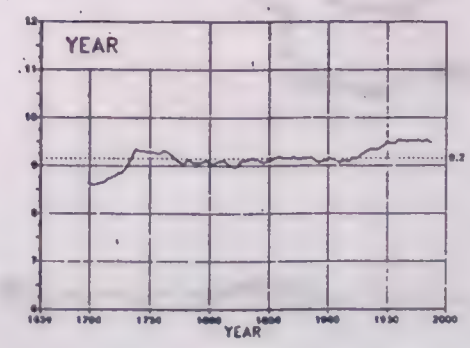


FIG 2 Locations of stations used

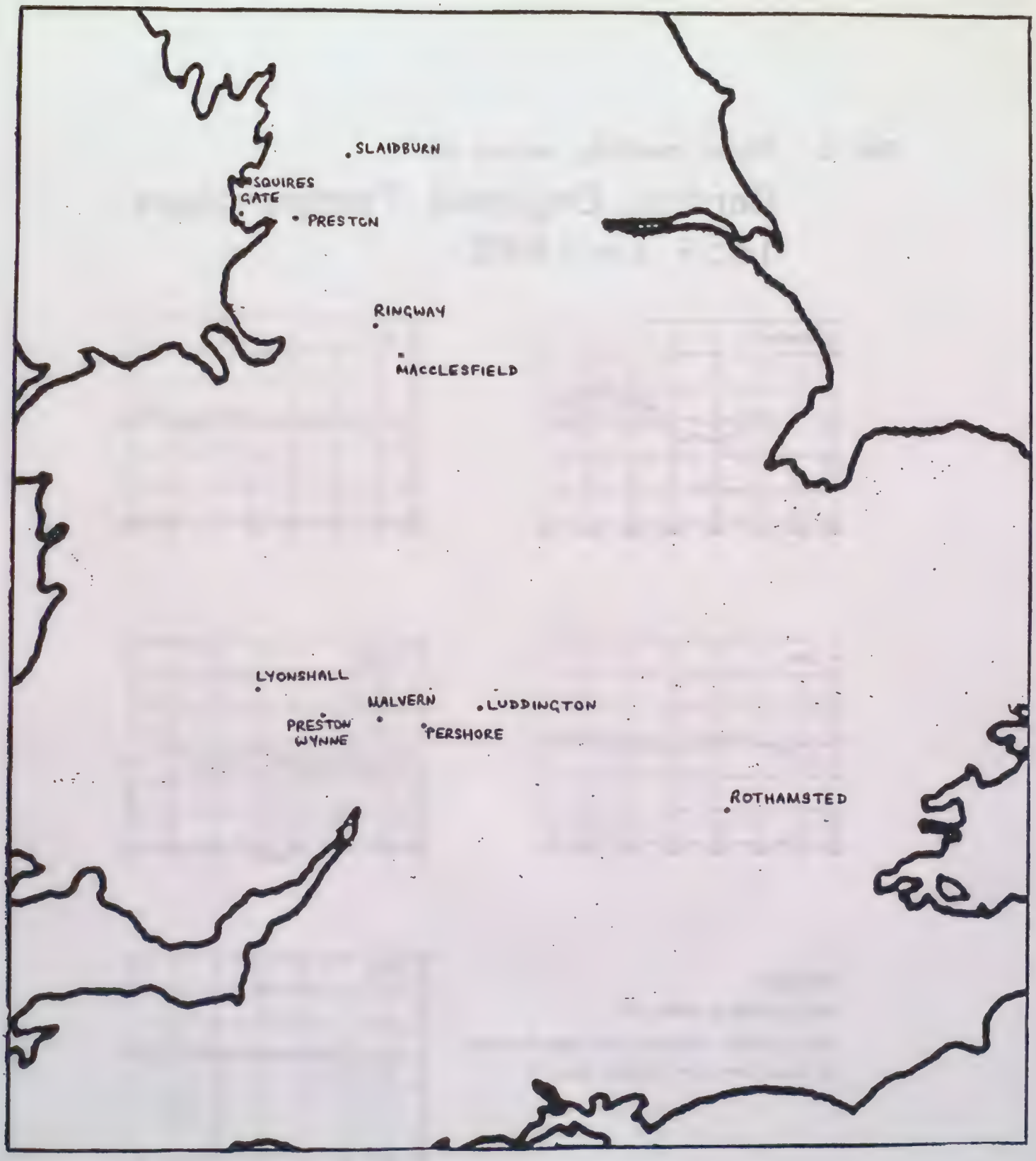
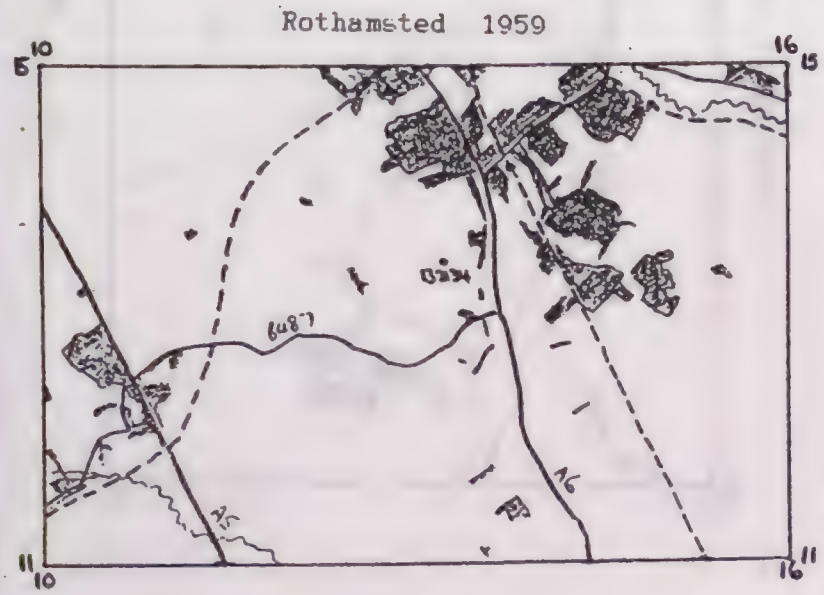
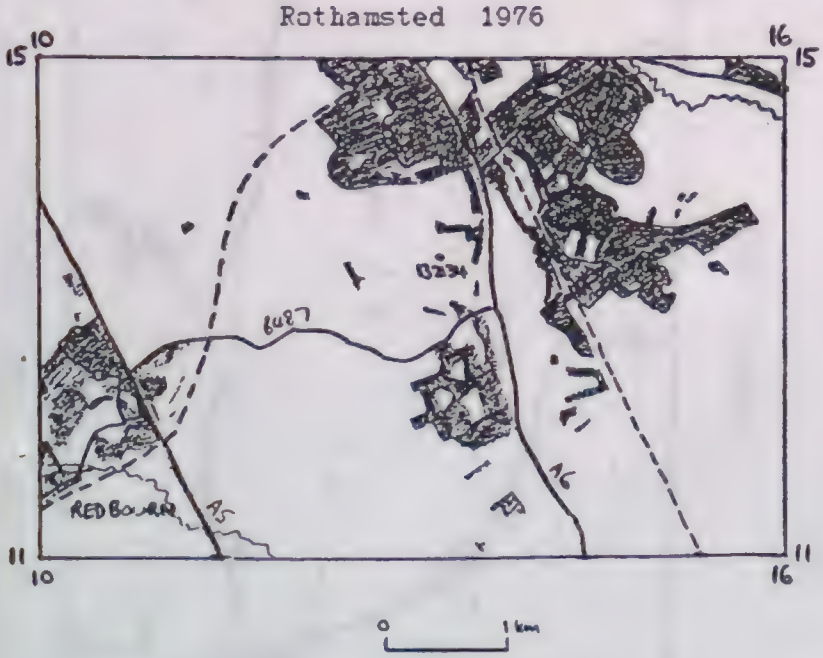
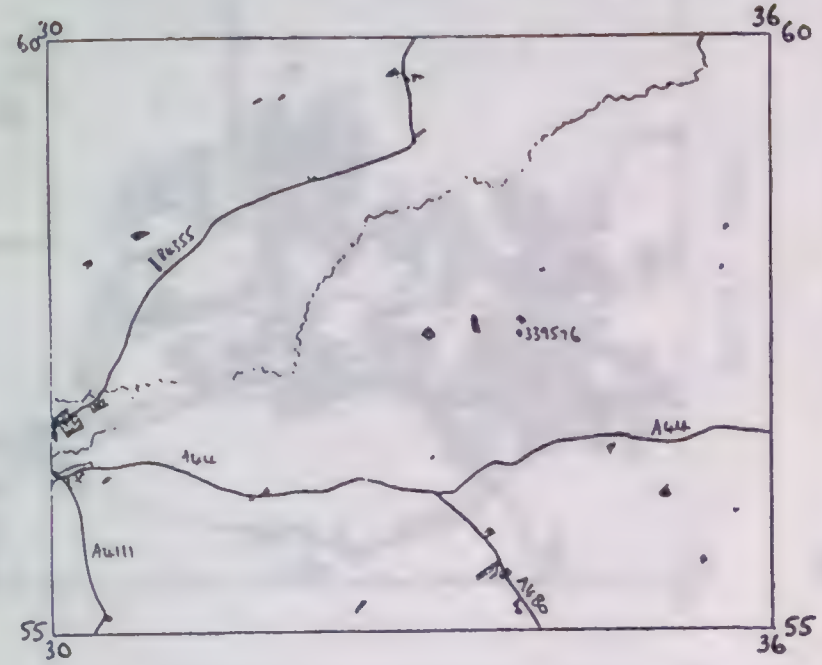


FIG 3. Old and new maps of environmental surroundings of stations showing extent of built-up areas

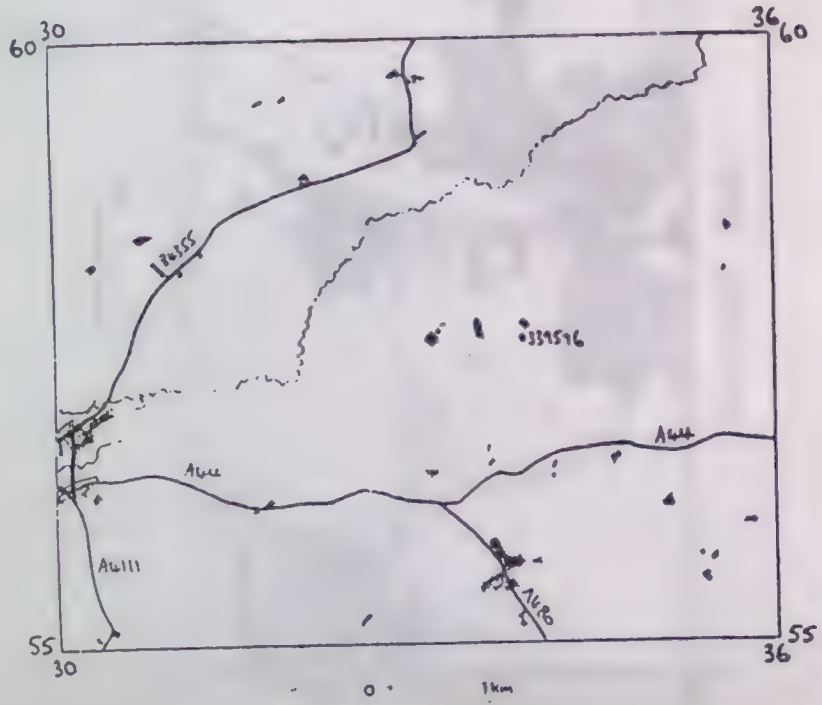




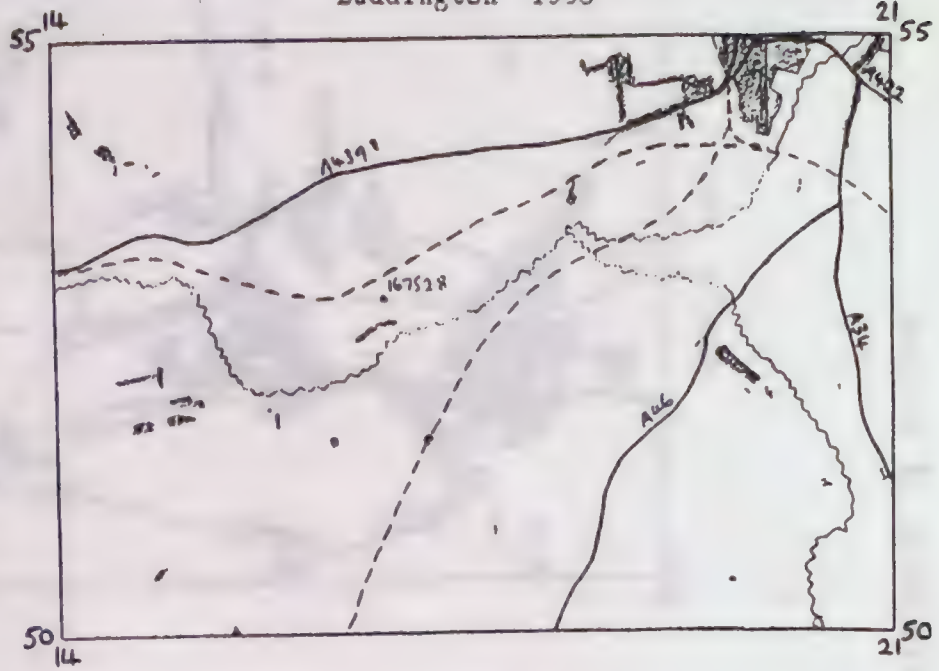
Lyonshall 1967



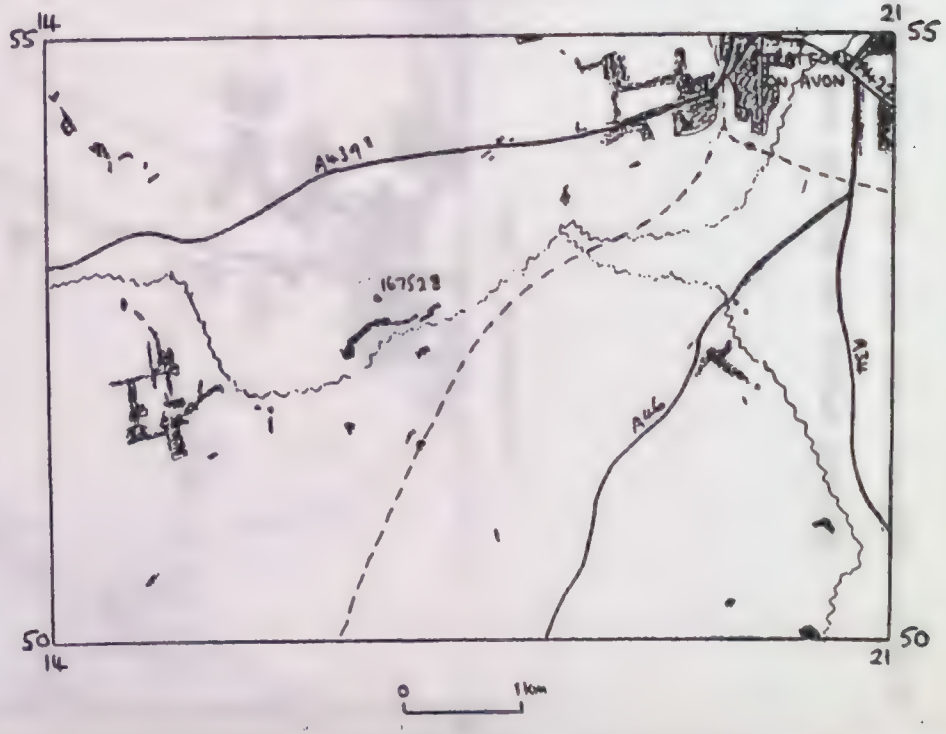
Lyonshall 1985



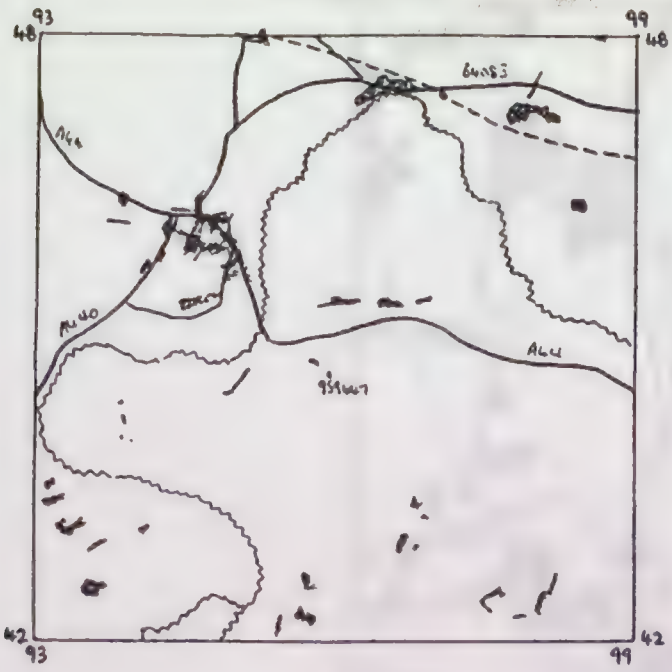
Luddington 1953



Luddington 1977



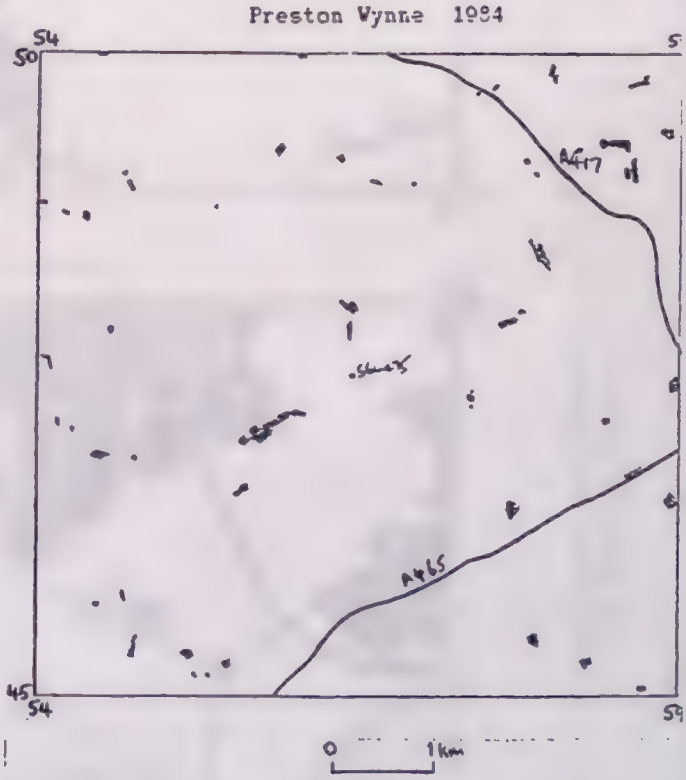
Pershore 1953



Preston Wynne 1974

Pershore 1987

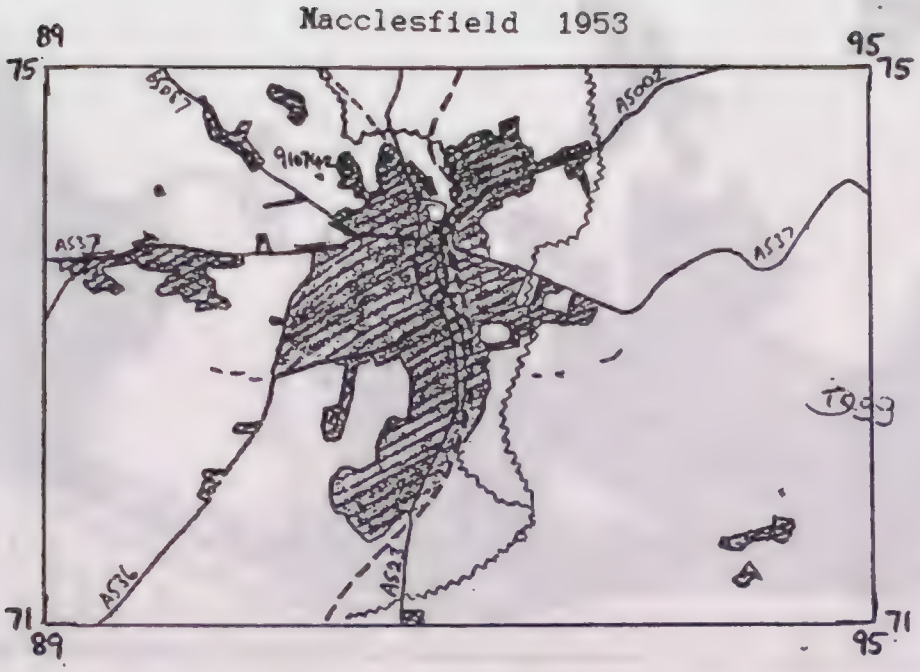
Preston Wynne 1984



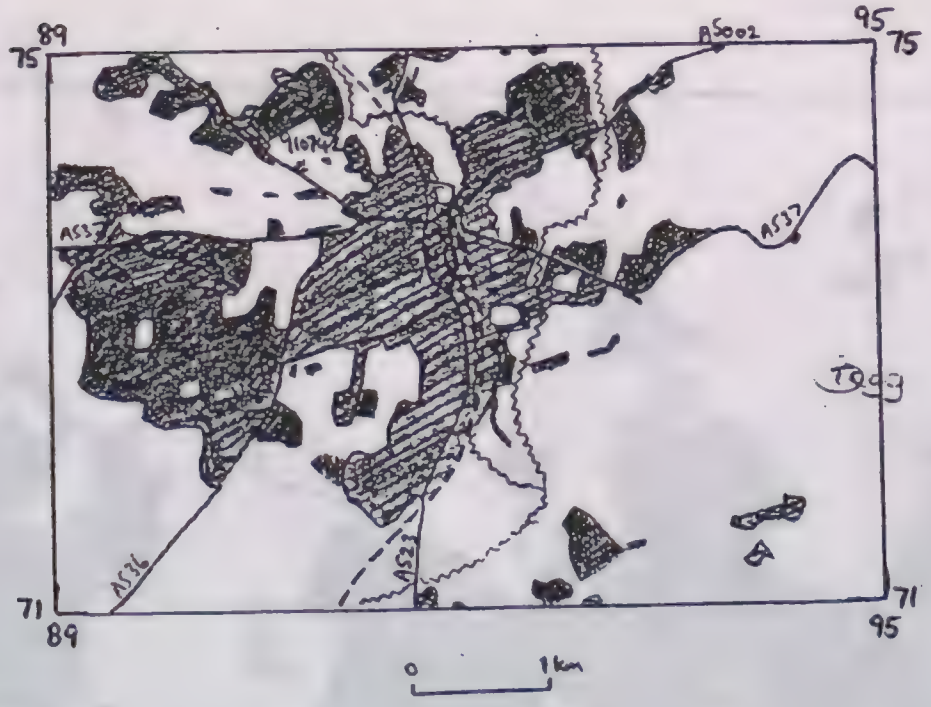
Ringway 1953

Ringway 1983

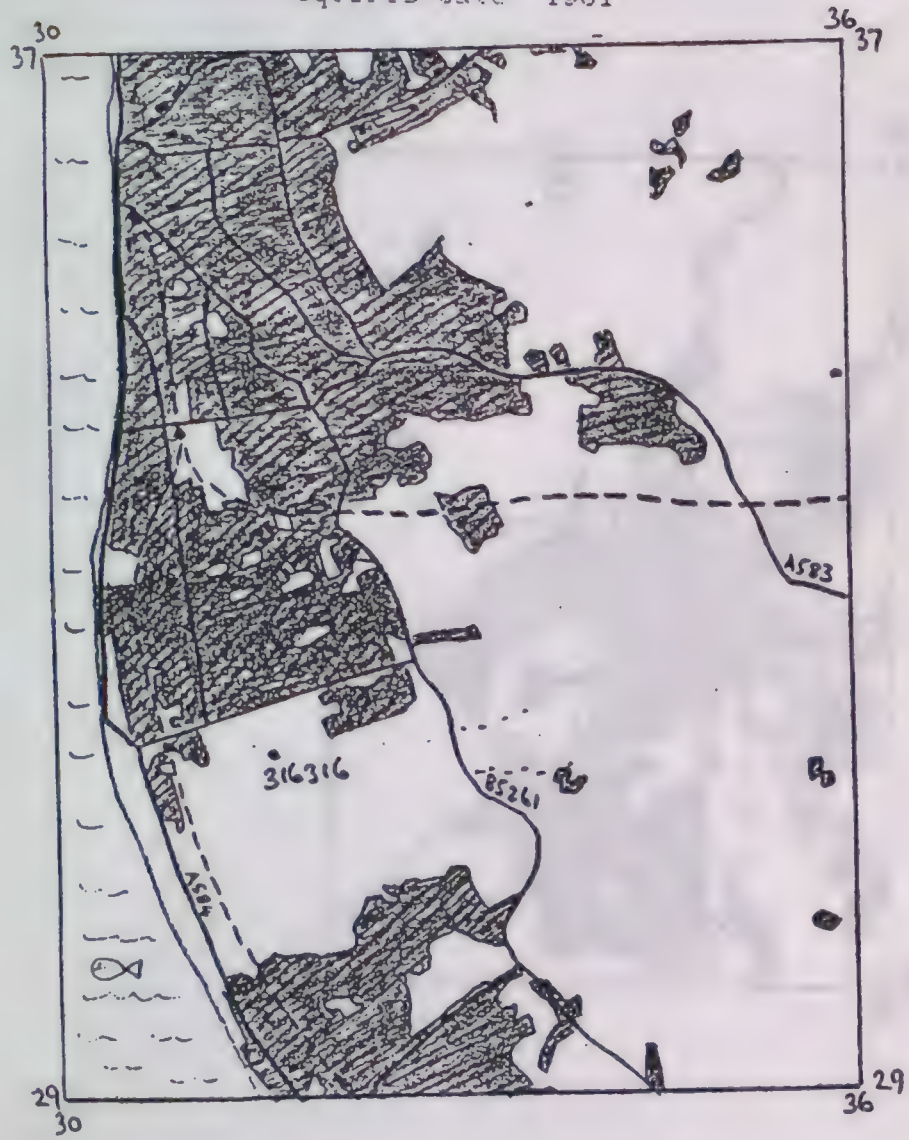
Macclesfield 1953



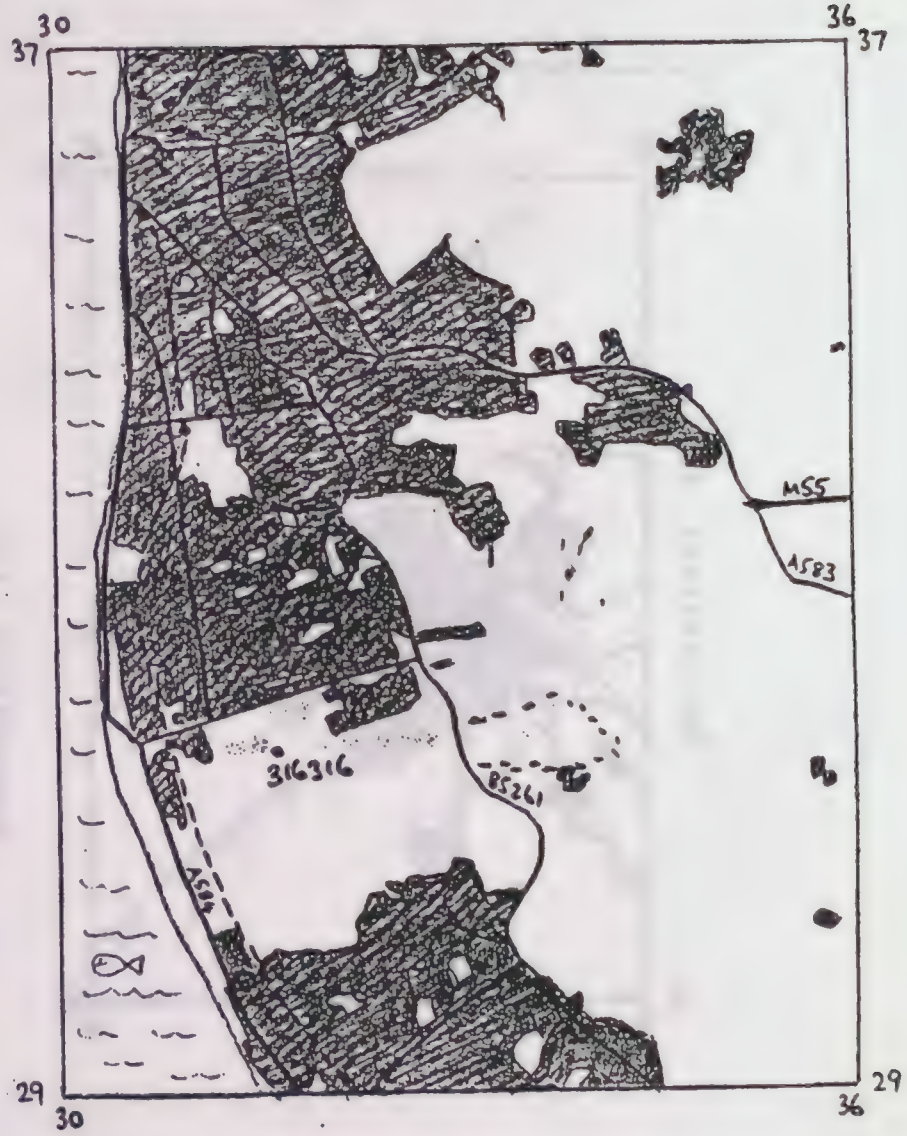
Macclesfield 1975



Squires Gate 1961



Squires Gate 1983



0 1km

Preston 1961

Preston 1983

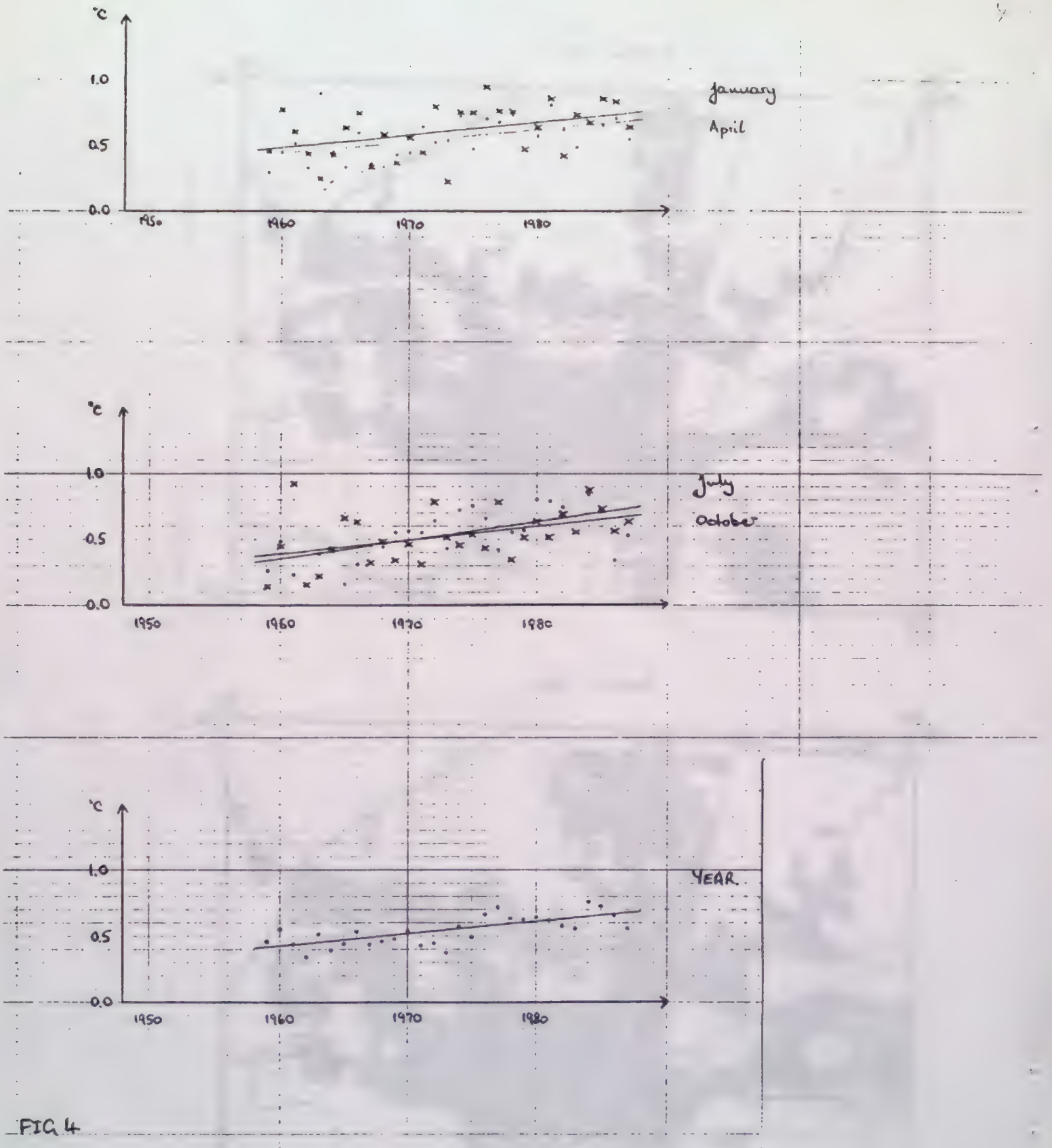


FIG 4

First Graphs: Warming of Ringway relative to Macclesfield, for selected months of the year and for the year as a whole, 1959-1987.

FIG 4 (cont.)

Second Graph: Warming of Malvern relative to Luddington, for selected months of the year and for the year as a whole, 1959-1987.

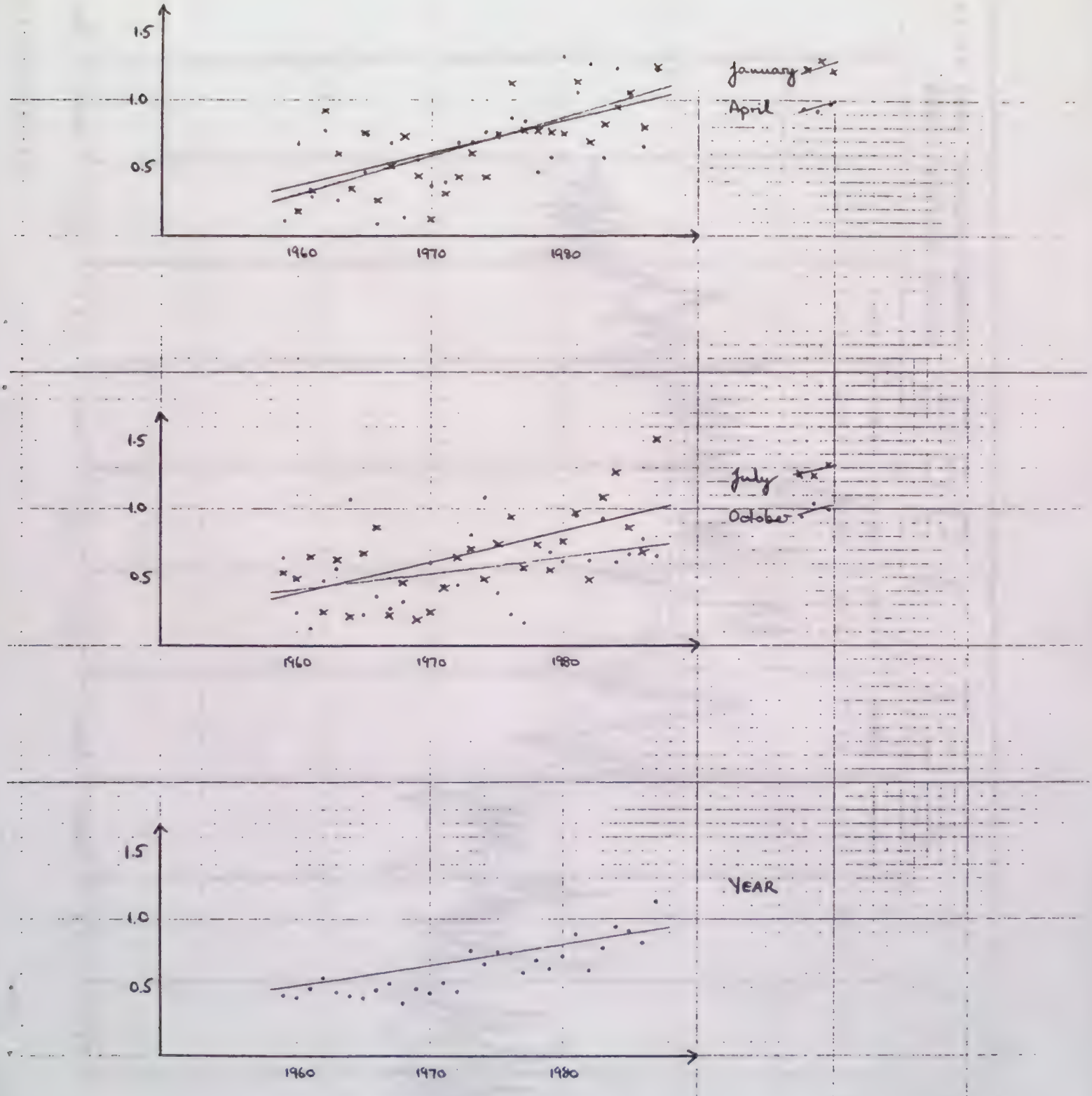
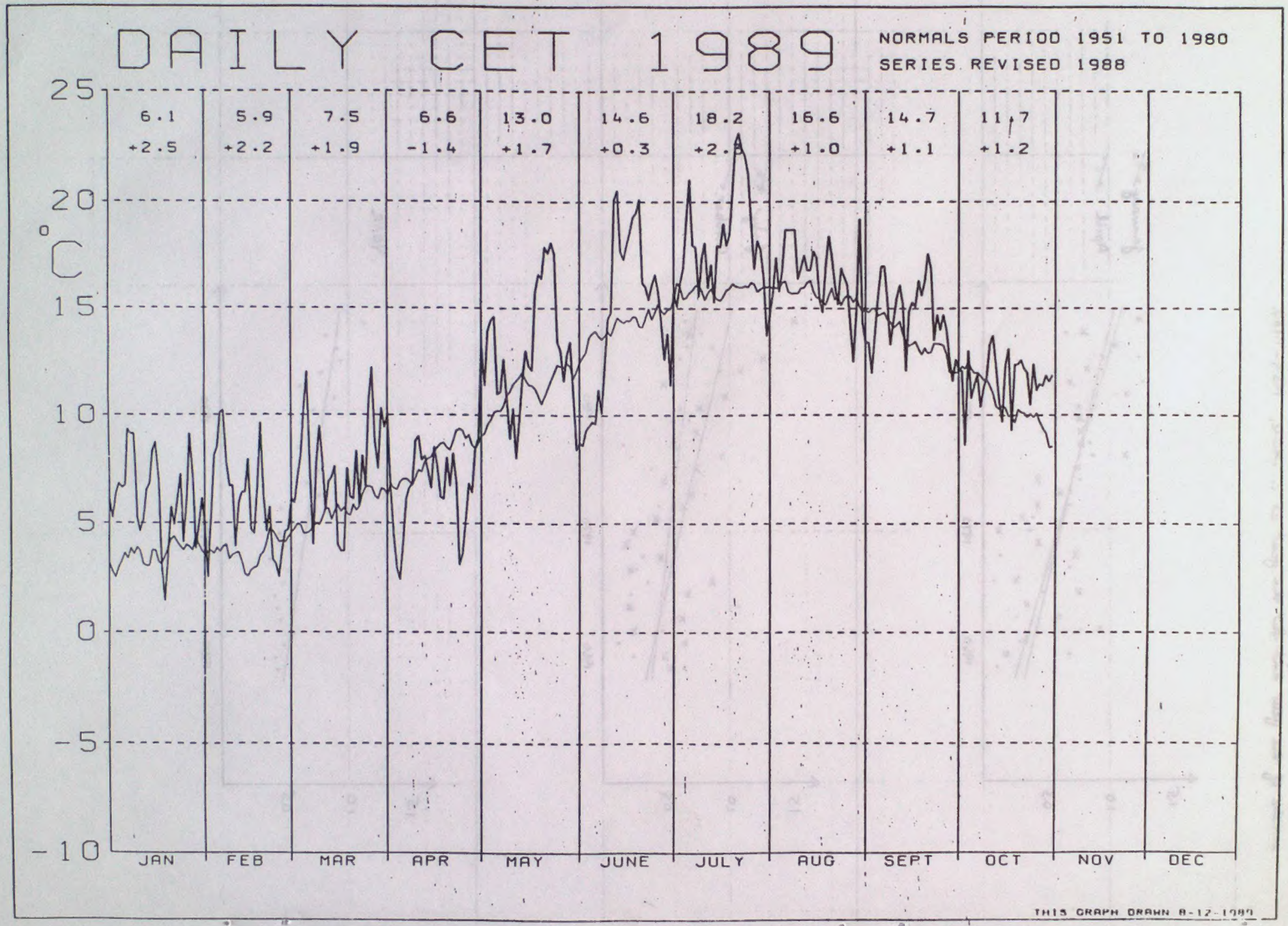


FIG 5


DAILY CET 1989
NORMALS PERIOD 1951 TO 1980
SERIES REVISED 1988
6.1 +2.5
5.9 +2.2
7.5 +1.9
6.6 -1.4
13.0 +1.7
14.6 +0.3
18.2 +2.8
16.6 +1.0
14.7 +1.1
11.7 +1.2
25
20
°C
15
10
5
0
-5
-10
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
THIS GRAPH DRAWN 8-12-1989

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